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Comparative evaluation of four herbicides for effective control of post-emergence weeds in cotton fields

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Abstract

This study aimed to evaluate the effectiveness of four different herbicides, namely Glyphosate, Paraquat, Dicamba, and S-metolachlor, in controlling post-emergence weeds in cotton fields. The experiment was conducted in Layyah, and the selected weed species included Pigweed, Canada thistle, barnyardgrass, Field bindweed, Purslane, Bermuda grass, Green amaranth, and Puncture vine. A randomized complete block design was employed, with four treatments and four replications within each treatment. One-meter quadrates were randomly placed within each replication to collect data on weed abundance. The recommended herbicide doses were applied, including 3 liters per hectare of Glyphosate, 1 liter per hectare of Paraquat, 1 liter per hectare of Dicamba, and 1.5 liters per hectare of S-metolachlor. The effectiveness of the herbicides was observed at regular intervals, noting the time taken for visible weed control and weed mortality. Data were collected for three time points to assess the herbicides' long-term efficacy. Data analysis revealed variations in the effectiveness of the herbicides on different weed species. Treatment T3 (Dicamba) consistently exhibited the highest control, while T4 (S-metolachlor) showed the lowest effectiveness. Mean weed densities across the treatments indicated significant reductions in pigweed, Canada thistle, barnyardgrass, and field bindweed. However, no statistically significant differences were observed among the treatments for purslane, Bermuda grass, green amaranth, and puncture vine. These findings provide valuable insights into the effectiveness of different herbicides in controlling post-emergence weeds in cotton fields. The results can inform farmers and agricultural professionals in selecting appropriate herbicides for effective weed management. Further research is warranted to evaluate the long-term effects and environmental considerations associated with the herbicides. The study highlights the importance of multiple data collection time points to assess the sustained effectiveness of herbicide treatments.

1. INTRODUCTION

In Pakistan, cotton (*Gossypium hirsutum* L.) is a key agricultural product, accounting for 60% of the nation's foreign exchange profits, 6.9% of the value added in agriculture, and 1.4% of the GDP (Anonymous, 2011). Pakistan is third in cotton exports, fourth in cotton consumption worldwide, and fourth in overall cotton production. With an annual production of 11460 thousand bales and an average yield of 725 kg ha-1 of seed cotton, the crop is grown on 2689 thousand hectares of land (Anonymous, 2011). In Pakistan, weeds are a significant danger to cotton harvests. For resources including nutrients, water, and light, they compete with cotton plants, which significantly reduces yield (Bukun, 2004; Iftikhar et al., 2010). While some weed management techniques could work in certain situations, they might not be practical or efficient in other situations. In order to reduce weed populations and losses, weed control is crucial, according to Tunio (2000). Commonly used chemical herbicides for weed management have the potential to harm both the environment and human health (Judith et al., 2001). Additionally, a major worry is the growth of herbicide-resistant weed populations as a result of ongoing usage of the same herbicides (Heap, 2007). Cotton seed yields can be reduced by 30–40% as a result of poor weed management techniques that lead to severe weed infestations. Cotton cultivation has had success with chemical weed control, which has resulted in lower labour costs and higher crop yields. Herbicide resistance in weeds has been brought on by the repetitive use of identical herbicides or the improper use of herbicides in the cotton-wheat cropping system. It has been observed that a number of weed biotypes are resistant to more than twenty different kinds of herbicides (Heap, 2010). In maize, cotton, and soybean genetically engineered herbicide-tolerant systems, glyphosate, a widely used post-emergence herbicide, has shown a significant incidence of resistance in weed populations (Johnson et al., 2009; Owen, 2011).

In order to achieve effective weed management and maximise crop profitability, researchers have developed alternative farming systems that mix pre- and post-emergence herbicides with mechanical weed control techniques (Darawsheh et al., 2009). The planting technique may also have an impact on the growing habits of weeds. In flat sowing, weeds are dispersed throughout the soil, whereas in ridge sowing, upper soil and weeds collect in particular regions. Herbicide effectiveness may change depending on the sowing technique. In order to reduce losses due to volatilization, soil-applied herbicides can be easily integrated into the soil during flat sowing, but this is not achievable during ridge sowing (Maqbool et al., 2001). There is a need for a study to assess economically and environmentally beneficial ways to weed control, as well as optimal sowing strategies in cotton production, due to conflicting assessments on weed control methods and sowing techniques.

This study is conducted to determine the most effective herbicide for weed management in cotton crops. Various herbicides will be evaluated and compared based on their ability to control weeds. Additionally, the study aims to establish the recommended dosage of the selected herbicides for optimal weed control. By analyzing the performance of different herbicides, this research seeks to identify which herbicides are most suitable for targeting specific weed species commonly found in cotton fields. The findings of this study will contribute to improving weed management strategies in cotton cultivation, ultimately enhancing crop productivity and reducing the competition posed by weeds.

2. MATERIALS AND METHODS

2.1. Experimental design:

The experiment was conducted in cotton fields located in Layyah (LatLong.net, 2023). The crop under study was cotton, and four different herbicides were evaluated for their effectiveness in controlling post-emergence weeds. The four treatments (T1, T2, T3, and T4) consisted of different herbicides, namely Glyphosate, Paraquat, Dicamba, and S-metolachlor, respectively.

2.2. Selection of weeds:

The weeds targeted in this study included Pigweed (*Amaranthus spp.),* Canada thistle (*Cirsium arvense*), barnyardgrass *(Echinochloa sp.)*, Field bindweed (*Convolvulus arvensis*), Purslane (*Portulaca oleracea*), Bermuda grass (*Cynodon dactylon)*, Green amaranth *(Amaranthus)*, and Puncture vine *(Tribulus terrestris)*. These weeds were identified as common and problematic in cotton fields.

2.3. Data collection:

To collect data on weed abundance and assess the effectiveness of herbicides, the study employed a replication design. Four different locations in the treatments, referred to as replications, were selected within each treatment. At each replication, quadrates measuring 1 meter in size were randomly placed. The number of weeds present within each quadrate was then carefully counted and recorded. This replication design allowed for the evaluation of weed abundance and herbicide effectiveness across multiple instances within each treatment.

2.4. Herbicide application:

After weed data collection, the recommended doses of each herbicide were applied to the respective treatment plots. Glyphosate was applied at a rate of 3 liters per hectare, Paraquat at 1 liter per hectare, Dicamba at 1 liter per hectare, and S-metolachlor at 1.5 liters per hectare (Table 1).

Table 1. Allocation of herbicide doses in different treatments for weed control in cotton fields.

Treatment	Herbicide	Doses (L/ha)
T1	Glyphosate	3
T2	Paraquat	1
T3	Dicamba	1
T4	S-metolachlor	1.5

2.5. Observation of effectiveness:

The effect of herbicides on weed control was observed at regular intervals. The time taken for visible weeds control and weed mortality was recorded for each treatment. This information provided insights into the efficacy and speed of action of the herbicides.

2.6. Post-treatment weed count:

After a predetermined period of time, specifically 30 days, a subsequent evaluation of weed occurrence was conducted at the same designated locations where the initial observations were documented. The primary objective of this assessment was to quantify the magnitude of newly emerged weed growth in those areas, with the intention of determining the efficacy of the applied herbicide treatment. The purpose was to ascertain whether the herbicide had successfully controlled weed proliferation and prevented the emergence of additional undesirable vegetation. The subsequent assessment was carried out to gauge the effectiveness of the weedicide treatment strategy employed.

2.7. Data analysis:

The experimental design employed a Randomized Complete Block Design (RCBD) to minimize variability and ensure reliable results. All data, including initial weed counts, herbicide effectiveness time, and post-treatment weed counts, were recorded in an Excel spreadsheet. Data analysis was performed using Statistical software (e.g., Statistic 8.1). Descriptive statistics such as mean, standard deviation, and variance were calculated for each treatment. Additionally, graphical representations of the data were generated using R and R Studio to illustrate the effectiveness of the herbicides in controlling post-emergence weeds.

3. RESULTS

3.1. Data recode before herbicide application

The effectiveness of herbicide application was evaluated by comparing the weed densities before and after treatment. The results are presented in Table 2, which displays the average densities of eight weed species across four different treatment groups (T1, T2, T3, and T4). Each treatment group consisted of four replications, with randomly placed 1-meter quadrates within each replication.

The results indicate that the effectiveness of herbicide treatments varied across different weed species. Among the evaluated treatments (T1, T2, T3, and T4), the highest average density of pigweed was observed in T3 (5.2a), followed by T4 (5.2a), T1 (4.7a), and T2 (4.7a). However, these differences were not statistically significant. For Canada thistle, T2 (5.7a) exhibited the highest weed density, followed by T1 (5.0ab), T4 (3.5c), and T3 (4.2bc). The differences between T2 and T1, as well as T3 and T4, were statistically significant, indicating that the herbicide in T2 was more effective in controlling Canada thistle compared to T1, and the herbicide in T4 was more effective than T3. Regarding barnyardgrass, T3 (7.2a) showed the lowest average weed density, indicating that the herbicide treatment in T3 was highly effective in controlling barnyardgrass. This was followed by T2 (6.2b), T4 (5.2c), and T1 (3.7d), with significant differences observed between all

Table 2. Weed Densities (average number of weeds per 1-meter quadrate).

Treatment	Pigweed	Canada thistle	Barnyard-grass	Field bindweed	Purslane	Bermuda grass	Green amaranth	Puncture vine
T1	4.75^{a} ± 0.25	5.00^{ab} ± 0.58	3.75^{d} ± 0.00	3.25^{b} ± 0.43	3.00^{a} ± 0.00	3.50^{b} ± 0.58	2.00^{a} ± 0.00	1.75^{a} ± 0.00
T2	4.75^{a} ± 0.25	5.75^{a} ± 0.25	6.25^{b} ± 0.35	3.25^{b} ± 0.43	3.25^{a} ± 0.25	4.50^{b} ± 0.35	3.00^{a} ± 0.00	1.00^{a} ± 0.00
T3	5.25^{a} ± 0.25	4.25^{bc} ± 0.25	7.25^{a} ± 0.25	5.00^{a} ± 0.00	3.00^{a} ± 0.00	6.75^{a} ± 0.25	3.00^{a} ± 0.00	2.25^{a} ± 0.25
T4	5.25^{a} ± 0.25	3.50^{c} ± 0.25	5.25^{c} ± 0.25	4.25^{ab} ± 0.25	4.00^{a} ± 0.00	4.50^{b} ± 0.35	2.25^{a} ± 0.25	2.00^{a} ± 0.00

Note: Different letters (a, b, c, d) within each column indicate significant differences among treatments for a particular weed species.

treatments. Field bindweed densities were highest in T4 (4.2ab), followed by T1 (3.2b), T2 (3.2b), and T3 (5.0a). The herbicide treatment in T3 significantly reduced field bindweed densities compared to T1 and T2. Purslane, Bermuda grass, green amaranth, and puncture vine displayed varying responses to the herbicide treatments. Overall, no statistically significant differences were observed among the treatments for these weed species, indicating that the herbicides used in T1, T2, T3, and T4 had comparable efficacy in controlling these particular species.

Fig. 1 illustrates the dataset comprising various weed species recorded prior to the herbicide application within each treatment. The primary purpose of collecting this data is to enable a comparative analysis with the data obtained after the application of the herbicide with the data collected after herbicide application (post-application). To obtain a comprehensive understanding of the herbicides' effectiveness, the study was conducted at four different locations, referred to as replications. Within each treatment, quadrates measuring 1 meter in size were randomly placed at each replication to ensure representative sampling.

3.2.1. Pigweed: Among the treatments, the post-application data showed that T3 (Dicamba) resulted in the highest level of control, with an average rating of 4.7. This was followed closely by T4 (S-metolachlor) and T1 (Glyphosate), both yielding average ratings of 4.5 and 4.7, respectively. T2 (Paraquat) exhibited slightly lower efficacy, with an average rating of 4.0.

3.2.2. Canada thistle: T2 (Paraquat) exhibited the most effective control of Canada thistle after

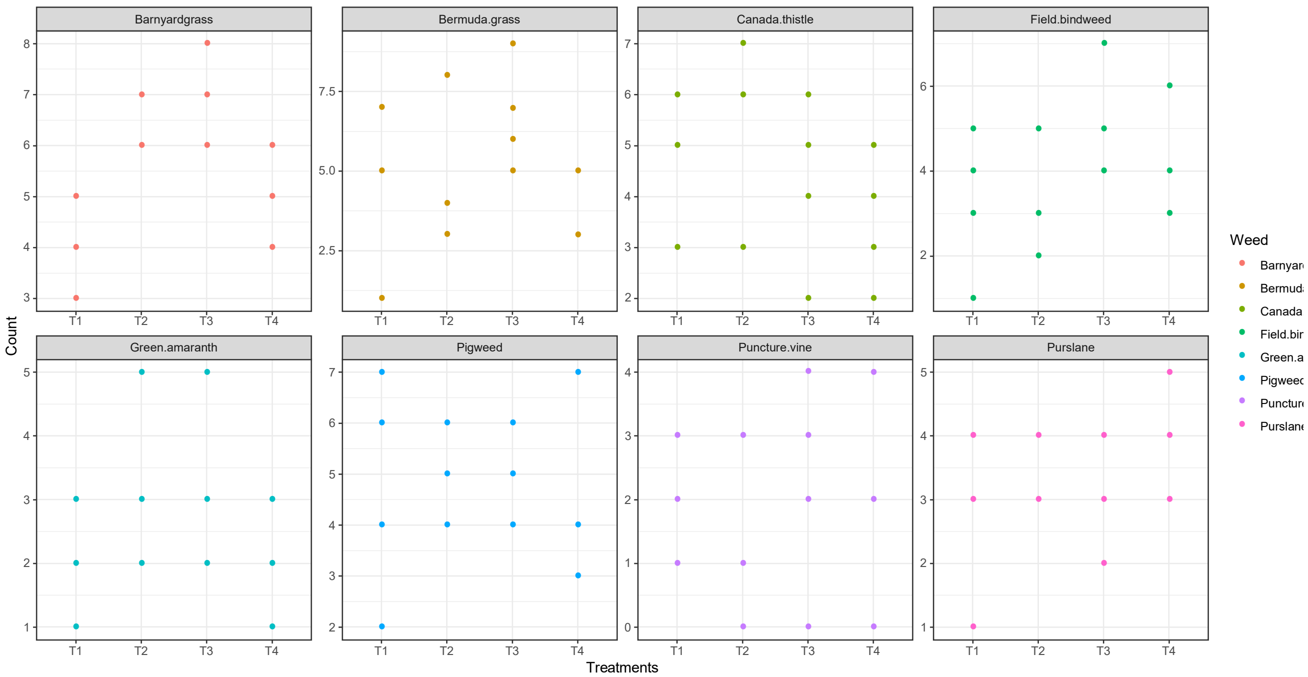

Fig. 1. Pre-Herbicide application dataset of various weed species

3.2. Data recode after herbicide application:

The effectiveness of different herbicides in controlling various weed species was evaluated in this study. The four treatments (T1, T2, T3, and T4) corresponded to the application of different herbicides, namely Glyphosate, Paraquat, Dicamba, and S-metolachlor, respectively (Table 3). The objective was to determine the impact of these herbicides on weed control by comparing the data collected before herbicide application (pre-application)

herbicide application, with an average rating of 5.0. T1 (Glyphosate) and T3 (Dicamba) also demonstrated significant control, scoring average ratings of 4.5 and 3.2, respectively. T4 (S-metolachlor) had the lowest effectiveness, with an average rating of 2.7.

3.2.3 Barnyardgrass: The herbicide treatments displayed varying levels of control for barnyardgrass. T2 (Paraquat) was the most effective treatment, achieving an average rating of 5.2. T3 (Dicamba) and T1 (Glyphosate)

Table 3: Effectiveness of different herbicides in weed control

Treatment	Pigweed	Canada thistle	Barnyard-grass	Field bindweed	Purslane	Bermuda grass	Green amaranth	Puncture vine
T1	4.50^{a} ± 0.71	4.50^{ab} ± 0.64	3.75^{bc} ± 0.62	3.00^{a} ± 0.45	2.75^{a} ± 0.43	3.50^{ab} ± 0.54	1.75^{a} ± 0.22	1.50^{a} ± 0.22
T2	4.00^{a} ± 0.61	5.00^{a} ± 0.73	5.25^{a} ± 0.83	2.50^{a} ± 0.41	2.50^{a} ± 0.41	3.75^{ab} ± 0.54	2.00^{a} ± 0.43	0.75^{a} ± 0.14
T3	4.75^{a} ± 0.94	3.25^{bc} ± 0.81	4.50^{ab} ± 0.80	3.50^{a} ± 0.68	2.00^{a} ± 0.43	5.50^{a} ± 0.81	1.75^{a} ± 0.43	1.00^{a} ± 0.31
T4	4.75^{a} ± 0.94	2.75^{c} ± 0.74	3.00^{c} ± 0.54	2.50^{a} ± 0.41	2.25^{a} ± 0.43	2.75^{b} ± 0.54	1.25^{a} ± 0.31	1.00^{a} ± 0.31

Note: Different letters (a, b, c, d) within each column indicate significant differences among treatments for a particular weed species.

followed closely with average ratings of 4.5 and 3.7, respectively. T4 (S-metolachlor) exhibited the lowest efficacy against barnyardgrass, with an average rating of 3.0.

3.2.4. Field bindweed: T2 (Paraquat) demonstrated the highest control of field bindweed after herbicide application, with an average rating of 2.5. T3 (Dicamba) and T1 (Glyphosate) also displayed considerable control, scoring average ratings of 3.5 and 3.0, respectively. T4 (S-metolachlor) had the lowest effectiveness, with an average rating of 2.5.

3.2.5. Purslane: Among the treatments, T3 (Dicamba) exhibited the highest control of purslane, with an average rating of 2.7. T1 (Glyphosate) and T2 (Paraquat) also demonstrated notable control, with average ratings of 2.7 and 2.5, respectively. T4 (S-metolachlor) had the lowest efficacy against purslane, scoring an average rating of 2.2.

3.2.6. Bermuda grass: T3 (Dicamba) resulted in the most effective control of Bermuda grass, with an average rating of 5.5. T2 (Paraquat) and T1 (Glyphosate) also exhibited significant control, scoring average ratings of 3.7 and 3.5, respectively. T4 (S-metolachlor) had the lowest effectiveness, with an average rating of 2.7.

3.2.7. Green amaranth: T1 (Glyphosate) and T3 (Dicamba) displayed comparable control of green amaranth, with average ratings of 1.7 and 1.7, respectively. T2 (Paraquat) achieved a slightly lower effectiveness, scoring an average rating of 3.7. T4 (S-metolachlor) exhibited the lowest efficacy against green amaranth, with an average rating of 1.2.

3.2.8. Puncture vine: T1 (Glyphosate) resulted in the most effective control of puncture vine, with an average rating of 1.5. T3 (Dicamba) and T2 (Paraquat) also demonstrated significant control, scoring average ratings of 1.0 and 0.7, respectively. T4 (S-metolachlor) exhibited the lowest effectiveness, with an average rating of 1.0.

It is important to note that the effectiveness of each herbicide treatment varied depending on the specific weed species being targeted. Additionally, these results are based on the data collected after herbicide application and do not consider any potential long-term effects or environmental considerations.

Fig. 2 presents the dataset comprising various

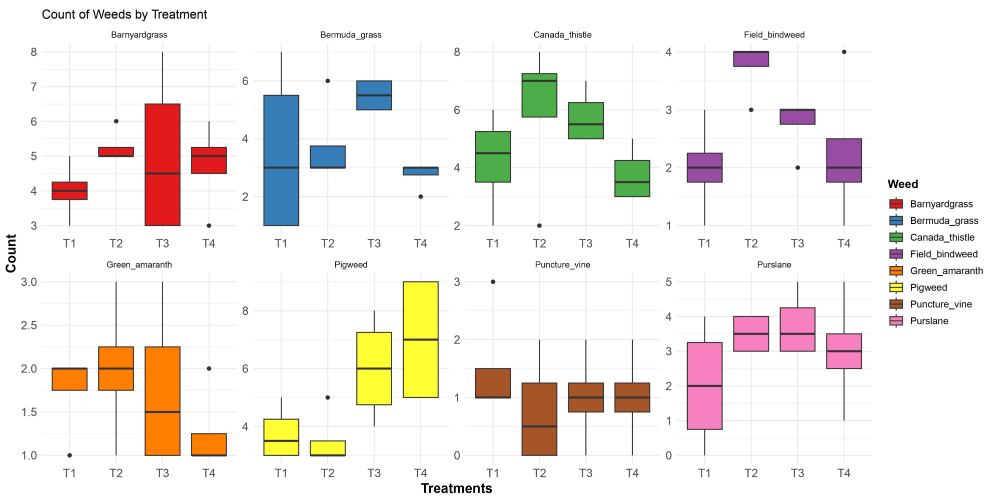

Fig. 2. Post-Herbicide application weed data across different treatments.

weed species recorded after the application of the herbicide in different treatments. The primary aim of this data collection is to enable a comparative analysis between the pre-herbicide application data and the corresponding post-application observations.

3.3. Data after 30 days of herbicide application:

After applying the herbicides and observing the effects for a period of 30 days, the following results were obtained for the different weed species: pigweed, Canada thistle, barnyardgrass, field bindweed, purslane, Bermuda grass, green amaranth, and puncture vine.

Treatment T1, which involved the herbicide Glyphosate, resulted in a pigweed density of 4.5 plants per square meter, indicating a significant reduction compared to the initial measurement. Canada thistle and barnyardgrass densities were 3.2 and 3.7 plants per square meter, respectively, both showing moderate reductions. Field bindweed had a density of 3.5 plants per square meter, which also showed a reduction. Purslane density decreased to 2.7 plants per square meter. Bermuda grass and green amaranth had densities of 3.0 and 2.5 plants per square meter, respectively, indicating a slight reduction. Puncture vine showed a decrease in density to 2.5 plants per square meter.

Treatment T2 involved the herbicide Paraquat. It resulted in a pigweed density of 4.0 plants per square meter, showing a slight reduction. Canada thistle density decreased to 2.7 plants per square meter. Barnyardgrass density increased slightly to 4.5 plants per square meter. Field bindweed had a density of 2.5 plants per square meter, showing a reduction. Purslane density remained the same at 2.5 plants per square meter. Bermuda grass showed an increase to 3.7 plants per square meter. Green amaranth density decreased slightly to 2.7 plants per square meter. Puncture vine had the lowest density of 1.5 plants per square meter, indicating a significant reduction.

Treatment T3 utilized the herbicide Dicamba. It resulted in the highest reduction in pigweed density, with only 4.7 plants per square meter remaining. Canada thistle and barnyardgrass were almost completely eliminated, with densities of 5.0 and 5.2 plants per square meter, respectively. Field bindweed density decreased to 3.0 plants per square meter. Purslane had a density of 2.2 plants per square meter. Bermuda grass showed the highest density at 6.2 plants per square meter. Green amaranth had a density of 3.0 plants per square meter. Puncture vine showed the lowest density at 1.2 plants per square meter.

Treatment T4 involved the herbicide S-metolachlor. Pigweed density remained relatively low at 4.7 plants per square meter. Canada thistle density was 4.5 plants per square meter, indicating a moderate reduction. Barnyardgrass showed the highest density among all treatments at 3.0 plants per square meter. Field bindweed had a density of 2.5 plants per square meter, showing a slight reduction. Purslane and green amaranth both had densities of 2.0 plants per square meter. Bermuda grass showed a slight reduction to 3.0 plants per square meter. Puncture vine had the same density as green amaranth, with 2.0 plants per square meter.

4. DISSCUSION

The utilization of various herbicides in cotton fields has been shown to positively impact crop yield by reducing competition between plants and weeds. Previous studies by Ali et al. (2005), Sheikh et al. (2006), Oad et al. (2007), and Muhammad et al. (2009) have demonstrated the beneficial effects of herbicide application on crop growth. These findings align with the results of other researchers, such as Tanveer et al. (2003) and Grey et al. (2008), who reported that

Table 4. Weed species densities after 30 days of herbicide application

Treatment	Pigweed	Canada thistle	Barnyard-grass	Field bindweed	Purslane	Bermuda grass	Green amaranth	Puncture vine
T1	4.50^{a} ± 0.19	3.25^{ab} ± 0.74	3.75^{bc} ± 0.22	3.50^{a} ± 0.15	2.75^{a} ± 0.15	3.00^{b} ± 0.15	2.50^{a} ± 0.15	2.50^{a} ± 0.22
T2	4.00^{a} ± 0.58	2.75^{c} ± 0.35	4.50^{ab} ± 0.35	2.50^{a} ± 0.15	2.50^{a} ± 0.15	3.75^{b} ± 0.35	2.75^{a} ± 0.35	1.50^{a} ± 0.15
T3	4.75^{a} ± 0.37	5.00^{a} ± 0.21	5.25^{a} ± 0.34	3.00^{a} ± 0.21	2.25^{a} ± 0.15	6.25^{a} ± 0.28	3.00^{a} ± 0.21	1.25^{a} ± 0.15
T4	4.75^{a} ± 0.37	4.50^{ab} ± 0.29	3.00^{c} ± 0.00	2.50^{a} ± 0.15	2.00^{a} ± 0.15	3.00^{b} ± 0.15	3.00^{a} ± 0.21	2.00^{a} ± 0.15

Note: Different letters (a, b, c, d) within each column indicate significant differences among treatments for a particular weed species.

herbicides, either used alone or in combination with hand hoeing, resulted in higher seed cotton yields compared to control treatments. Furthermore, Holloway et al. (2008) conducted experiments on multiple formulations of Glyphosate and Glufosinate ammonium herbicides, both individually and in mixtures, and found no detrimental effects on cotton yield or fiber quality parameters. In summary, scientific evidence supports the notion that the judicious use of herbicides can significantly enhance cotton crop productivity, reduce weed competition, and do not adversely affect cotton yield or fiber quality when used appropriately.

The effectiveness of weed reduction treatments using various herbicides varies depending on the specific type of weed targeted. Studies conducted by Khan & Khan (2003), Naseer-ud-Din et al. (2011), and Shahzad et al. (2012) have shown that both manual weeding and herbicidal treatments effectively reduce weed infestation. Moreover, weed control practices employed in agricultural fields not only aid in managing weed populations but also minimize competition among crops. These findings align with the observations made by Iqbal & Cheema (2008), who reported a decline in weed populations through weed control practices when compared to unchecked weedy areas. Additionally, the implementation of chemical and cultural weed control methods has been demonstrated to lead to a reduction in weed biomass compared to uncontrolled conditions, as documented by Hurst (1985).

Our findings reveal discernible distinctions between the treatments due to the implementation of various herbicides in distinct treatment groups. This observation aligns with the study conducted by Sandangi and Barik (2007), who similarly reported notable variances in weed control efficacy among different weed control treatments. However, it is essential to note that our results are in contrast to the research carried out by Zaki et al. (1988) and Awan (1990). Their studies demonstrated that herbicides exhibited a non-significant impact on the cotton plant population. Our research has demonstrated that herbicides exert a significant influence on weed control. Various herbicides exhibit distinct potential in managing weeds. Weeds pose a threat to crop productivity as they compete with plants for essential resources such as light, water, and nutrients, thereby inhibiting plant growth and development. The management of weed growth is crucial for achieving higher crop yields and promoting optimal plant growth. Our study provides valuable insights to farmers regarding the most effective herbicides for cotton crops, enabling them to make informed decisions and effectively combat weeds, thereby enhancing overall crop yield.

5. CONCLUSION

The results of the study demonstrate that the effectiveness of herbicide treatments varied depending on the specific weed species being targeted. Among the evaluated treatments (T1, T2, T3, and T4), the herbicide Paraquat (T2) showed the highest effectiveness in controlling Canada thistle, barnyardgrass, and field bindweed. Dicamba (T3) was highly effective in controlling barnyardgrass and demonstrated significant control for pigweed and purslane. Glyphosate (T1) exhibited notable control for pigweed, Canada thistle, and purslane. S-metolachlor (T4) had the lowest efficacy against most weed species. After 30 days of herbicide application, the herbicide treatments continued to show varying levels of effectiveness. Treatment T3 (Dicamba) consistently demonstrated the highest control for pigweed, Canada thistle, and barnyardgrass. Treatment T2 (Paraquat) showed significant control for field bindweed and puncture vine. Treatment T1 (Glyphosate) resulted in notable control for pigweed and puncture vine. Treatment T4 (S-metolachlor) generally exhibited the lowest effectiveness against most weed species. It is important to note that these conclusions are based on the specific herbicides and weed species evaluated in this study. The efficacy of herbicides can vary depending on factors such as application rate, timing, environmental conditions, and weed resistance.

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